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MANUFACTURE OF ROQUEFORT TYPE CHEESE FROM GOAT'S MILK

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S. A. HALL* AND C. A. PHILLIPS†

The milk goats in California produce more milk than the present market can use fresh. Many goat farms are located in isolated places, from which it is impracticable to ship out fresh milk. The result is an unutilized surplus. The manufacture of cheese from goat's milk has been suggested as a use for this surplus, and experiments to manufacture cheese of Roquefort type have been made. The Roquefort cheese process, as perfected in France, employs sheep's milk. In America, a similar cheese has been made successfully from cow's milk by the Bureau of Dairying of the United States Department of Agriculture.¹ The chief defect of the cow's milk cheese is its yellow color, due to the large amount of coloring matter in the milk. Goat's milk, which is similar to sheep's milk in color and body, produces Roquefort type cheese of excellent quality.

CARE OF THE MILK

The same care and skill necessary in the production of clean milk of any kind should be used when producing goat's milk for Roquefort cheese. All utensils, buckets, strainers, coolers, etc., should be thoroughly cleansed and sterilized. The milking sheds should be kept clean and free from barnyard dust. The flanks and udders of the goats should be clean at the time of milking. Bucks should be kept a considerable distance from the milking sheds in order that disagreeable odors may not be taken up by the milk. The evening milk should be cooled immediately after milking to 50°-60°F. and held at that temperature over night. Though it is desirable to cool the morning milk also, cheese of satisfactory quality can be made from the warm milk if it is used within two or three hours after milking. In this case, the warm morning milk should be brought to the factory in separate cans where it may be mixed with the cool evening milk by the cheese maker.

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COMPOSITION OF COW'S, SHEEP'S, AND GOAT'S MILK

Goat's milk, unlike sheep's milk, does not differ greatly in percentage composition from cow's milk.

TABLE 1
AVERAGE PERCENTAGE COMPOSITION OF MILK

	Cow's milk*	Sheep's milk†	Goat's milk‡
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Water.....	87.27	79.5	86.09
Protein.....	3.39	6.5	3.55
Fat.....	3.68	8.0	4.79
Sugar.....	4.94	4.5	4.85
Ash.....	.72	1.0	.72

* Heineman, P. G. Milk: 70. 1921.

† Matheson, K. J. Manufacture of cow's-milk Roquefort cheese. U. S. Dept. Agr. Bul. 970; 6. 1921.

‡ Voorhies, E. C. The milk goat in California. Calif. Agri. Exp. Sta. Bul. 285; 9. 1921.

The analysis of the goat's milk used in the manufacture of Roquefort type cheese at the University Farm showed considerably less total solids and fat than is given in table 1.

COMPOSITION OF ROQUEFORT CHEESE

Table 2 shows the composition of several samples of the highest quality Roquefort cheese analyzed by Dox.*

TABLE 2
AVERAGE PERCENTAGE COMPOSITION OF ROQUEFORT CHEESE

	Water	Fat	Protein	Ash	Salt
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Average.....	38.69	32.21	21.39	6.14	4.14
Minimum.....	37.49	31.50	19.14	5.18	3.64
Maximum.....	40.10	33.53	23.06	6.81	4.88

The results of analyses of goat's milk and cow's milk Roquefort type cheeses made in our experiments are shown in table 3.

* Matheson, K. J. Manufacture of cow's milk Roquefort cheese. U. S. Dept. Agr. Bul. 970:3. 1921.

TABLE 3
AVERAGE PERCENTAGE COMPOSITION OF ROQUEFORT TYPE CHEESE

	Water	Fat	Fat in dry matter	Salt
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Goat's milk Roquefort.....	43.78	25.41	45.19	5.38
Cows' milk Roquefort.....	46.06	27.16	50.35	5.46

THE MANUFACTURE OF GOAT'S MILK ROQUEFORT CHEESE

In the manufacture of this cheese at the University Farm, the methods outlined in France by Marre,² and in this country by Matheson¹ were used with some modifications.

Acidity.—As previously stated, fresh clean milk is necessary for making Roquefort cheese. The acidity should be between .16 and .18 percent for the best results. Over-ripe milk is likely to result in a gassy cheese and sometimes an objectionable flavor. From 3 to 4 per cent of good clean lactic starter should be used according to the acidity of the milk and starter.

Temperature.—For sheep's milk the temperature of setting used in France is from 76° to 84°F. Cow's milk should be set at 82° to 85°F., and goat's milk at 82°F. When goat's milk was set above this temperature, difficulty was encountered with cracking of the curd. When 20 per cent of cow's milk was added to the goat's milk this difficulty was overcome. When combinations of cow's and goat's milk are used, it is advisable to set the milk at 84°F. A lower temperature is liable to result in a soft, mushy curd which fails to drain properly, while a higher temperature may result in a tough curd.

Setting and rennet.—The milk is heated in an ordinary cheese vat and stirred to insure even distribution of fat and heat. After the acidity has developed to .21 or .22 per cent, commercial rennet diluted from twenty to forty times with pure cold water is added to the milk, which is then agitated thoroughly.

Time for coagulation.—The setting period should be approximately one and one-half hours, but varies with the acidity, temperature, and quality of the milk. At first, beads of whey, then a film of whey, gradually spreads over the surface of the curd, indicating that it is

ready to cut. The curd is cut two ways with a coarse, vertical knife with wires $\frac{5}{8}$ in. to 1 in. apart. Soon after this, the curd slowly contracts and draws away from the sides of the vat. This contraction should not be allowed to go too far, however, before dipping the curd.

Draining the curd.—A cheddar cheese vat similar in capacity to that in which the milk was set, makes an excellent drain vat, if it is provided with a false bottom covered with cheese cloth or muslin of good quality. The two vats should be placed near enough together



Fig. 1.—Sprinkling mold powder between layers of curd in the hoops.

to permit two or three workers to do the dipping. Large tin scoops, each with a capacity of three or four quarts, are suitable for this purpose.

The curd should be transferred to the drain vat rapidly and carefully. Two men should be able to take the curd from 1500 pounds of milk in from ten to fifteen minutes.

Raising the cloths from time to time aids in expelling the whey and in bringing the draining curd to the proper condition of dryness. The time required for draining is from twenty to forty minutes, according to how often the clothes are raised during this period. The curd should be placed in the forms in a fairly moist condition. When it is too dry, the surface of the cheese becomes so open and rough, that undesirable organisms may have access to the interior. Greater losses occur in the curing process when such conditions exist.

Butterfat losses.—The whey should be drawn from the drain vat and run through a whey separator. The average fat loss from goat's milk is from 0.50 to 0.60 per cent, while that from cow's milk is from 0.20 to 0.30 per cent. When 20 per cent of cow's milk is added to goat's milk, the fat loss is reduced to about 0.40 per cent. It is probable that a satisfactory reduction of the loss would be obtained with somewhat less than 20 per cent addition of cow's milk.

Hooping and Inoculation.—The hoops (or forms) for Roquefort cheese are made of galvanized metal with wire edges. They are round and open on both ends, and are seven and three-eighths inches in diameter and six inches high. They have six horizontal rows of holes. Each row has twenty-five holes one-eighth inch in diameter. The hoops are placed upon special reed mats, ten by twenty-four inches. The mats are placed upon boards of approximately the same size, each of which will hold three hoops. Cloths may be used instead of mats, but they are not so satisfactory. All hoops, mats, and boards should be thoroughly cleaned and sterilized before using, to reduce the number of foreign molds which may appear later.

When it is put into the hoop, the curd is a white, pulpy mass and should contain only a small excess of whey. The hoop is filled with four or five layers of curd, between which liberal applications of mold powder are sprinkled.

Draining the cheese.—The drain room should have a temperature of 65°–68°F. and a relative humidity of 85–90 per cent to prevent the cheese from drying out. Higher temperatures favor the development of injurious molds. The cheese is left in the room about four days. It is turned several times during the first day and twice daily thereafter. The object of the repeated turnings is to hasten drainage and to insure a smooth, even surface. The hoops, which are allowed to remain around the cheese for the first one or two days, should be washed and sterilized before using again. The boards should be washed every day. The cheese is scraped each day while in the drain room in order to remove the coating of slime which forms over the surfaces.

Salting.—The salting room should be dry and should have a temperature of approximately 48°F. There should be sufficient ventilation to remove the excess of moisture drawn to the surface of the cheese by the salt.

The cheese should be salted two or three times at two-day intervals, according to the amount of salt desired and the conditions affecting its penetration. The cheese should be placed in the salting room several hours before the first salt is applied, in order to cool it to the

temperature of the room. Cheese salt is then rubbed vigorously over the surface, until no more will adhere.

After the cheeses are thus salted, they are piled two or three high, and the following day their positions reversed, with no addition

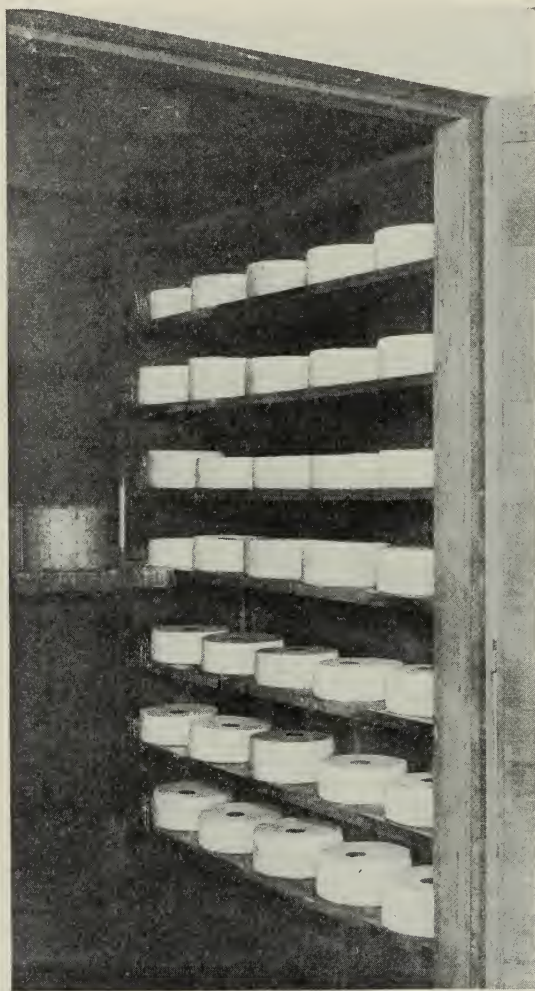


Fig. 2.—The drain room, where the cheese remains four or five days.

of salt. On the third day they are again salted in the manner previously described. On the fifth day they may receive a light sprinkling of salt for markets preferring a highly salted cheese.

The salting period should be from ten to fourteen days, according to the condition of the cheese.

Some experience is required to salt Roquefort cheese successfully, the usual tendency being to undersalt or to oversalt. Cured Roquefort cheese should contain at least 4 per cent of salt, an amount which is sufficient to prevent an excessive development of the mold, *Oidium lactis*. Most of the cheese made in these experiments contained from



Fig. 3.—A truck for transporting cheese from the drain room to the salting room.

5 to 6 per cent, which did not seem to injure the quality for most of the consumers, although some preferred less.

Scraping.—During the salting process a slimy coat, composed of softened cheese, whey, salt, and micro-organisms, begins to form. This coating is scraped off with an ordinary case knife. Care should be taken not to scrape the cheese too deeply, since, at this period, a high percentage of salt in the surface is essential.

Punching.—The cheese is punched immediately after the scraping. Oxygen is necessary for the proper growth of the Roquefort mold, and in order to let the air in, each cheese is punched with a needle in twenty to fifty places. The needles are about one-eighth inch in diameter and about eight inches long. The cheese is placed on edge after the punching in order that the holes may not be closed, and that the maximum amount of air may come in contact with the mold.

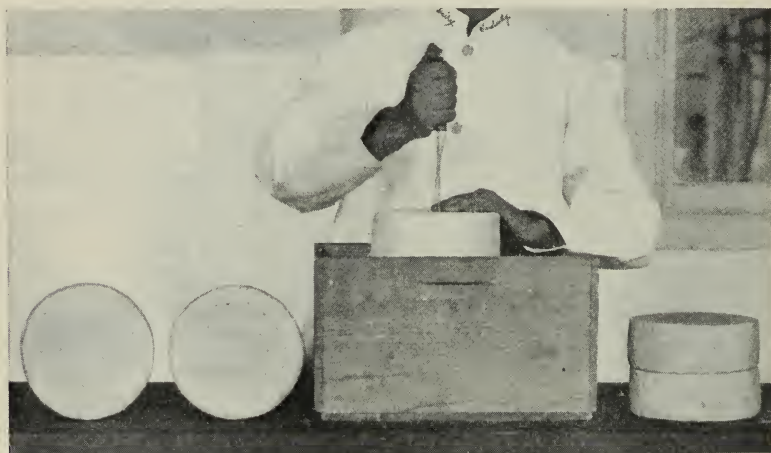


Fig. 4.—Punching the cheese with a needle to permit the entrance of air.

Ripening or curing.—The curing room should have a temperature of 42°–48°F., a relatively high humidity (about 92 per cent), and moderate ventilation.

TABLE 4

CONDITIONS FAVORABLE FOR CURING GOAT'S-MILK ROQUEFORT CHEESE

Period	Temperature	Relative humidity	Ventilation
	<i>Degrees F.</i>	<i>Per cent</i>	
First four days.....	65–68	85–90	Slight
Next ten days.....	46–48	80–90	Considerable
Third week.....	42–48	90–95	Moderate
Fourth and fifth weeks.....	42–48	90–95	Moderate
Second and third months.....	42–48	90–95	Moderate
Fourth and fifth months.....	46–48	80–90	Considerable

The humidity and ventilation indicated in table 4 cannot be expressed with any great degree of accuracy at the present time. The table shows in a general way, however, the conditions that have proved most successful. With experience, they can be controlled properly.



Fig. 5.—The cheese placed on edge on the curing shelves.

Curing rooms for Roquefort.—In the work at the University Farm, well-insulated curing rooms were used. The sides, tops and bottoms were insulated with four inches of cork laid in hot asphalt and covered with Portland cement plaster. Direct expansion ammonia refrigeration and brine coils were used in order to maintain the low temperature. A perforated water pipe was placed along the top of the room so that water could trickle down over a screen behind the shelves in order to maintain the proper humidity. Water cooled to room temperature is more economical than tap water, since the cost of refrigeration is lower. A vacuum cleaner motor was installed, and run

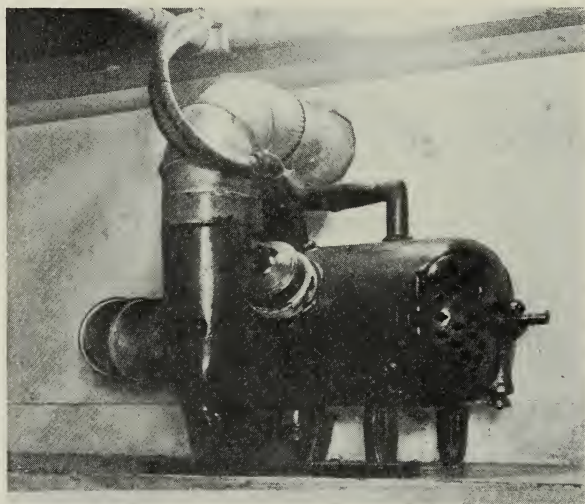


Fig. 6.—A vacuum cleaner motor used for circulation of air in small curing rooms.

continuously at low speed, in order to obtain the proper circulation of air. The air was drawn from the curing room and forced back again. Outside air was taken in only when the door was open.

During the first two or three weeks there should be a gradual development of a reddish slime upon the surface of the cheese, together with patches of white and green mold. In cases where the reddish slime fails to develop rapidly, scrapings may be obtained from other cheese. These, mixed with sterile water and then sprinkled on the cheese, give the desired growth without difficulty. This growth should be removed by scraping (see fig. 7), every three or four weeks in order to permit the air to reach the mold in the interior of the cheese. After this scraping there is only a slight development of the white and green mold, but there is much greater development of reddish slime.

Within ten days after punching, mold can be seen through the punched holes when the cheese is held before an electric light. Within two or three weeks or a month, there is probably as much green mold visible as when cheese is cut several months later. The mold in the center of the cheese appears to develop more rapidly than that nearer the surface, probably because of the difference in concentration of salt. In the earlier stages of ripening, the cheese often tastes bitter. Later this condition disappears and a sweet, piquant flavor is noticeable with little or no bitterness. With the proper curing conditions, the texture of goat's-milk Roquefort cheese can be made similar to that of the imported. In some cheese, in these experiments, there was a typical peppery flavor, often repellent to the taste. This is probably



Fig. 7.—Scraping the surface of the cheese with a case knife.

due to an intense oxidation as is evidenced by the formation of formic acid, which occurs when the cheese is held for a long period at a high temperature.¹

High humidity prevents the cheese from drying and increases the rapidity of the growth of the slime on the surface. No experimental data is available to show that the surface growth aids in the ripening of the cheese, but its presence is always associated with the best grades. This slime seems to check the growth of surface mold and to keep the cheese in a sweet, normal condition. Dryness causes the cheese to ripen slowly with a flavor lacking the characteristics of good Roquefort, and a texture which is too waxy.

The cheese may be taken from the curing shelves when about three months old, scraped for the last time, and wrapped in tin foil or aluminum foil. At this time there should be an abundance of mold and some flavor, but as a rule, the full flavor develops only after the cheese has been left in the foil for a few months.

Enclosing in the foil prevents drying, excessive oxidation, and the escape of the volatile substances. This also helps to develop the sweet flavor, and reduces the formation of strong, biting, and soapy flavors

which may occur when cheese is exposed too long to the air. Parchment paper is used to protect the foil. Paraffin cannot be used as a substitute for foil on account of the moist condition of the surface of the cheese. It will not protect the cheese so well and does not make an attractive appearance.

Roquefort cheese from goat's milk requires from four to seven months to ripen. When ripened it may be placed in cold storage at about 34°F. for eight months to one year in order that a uniform supply of cheese may be placed on the market throughout the year. During this storage, the cheese should become sweeter and more fragrant.

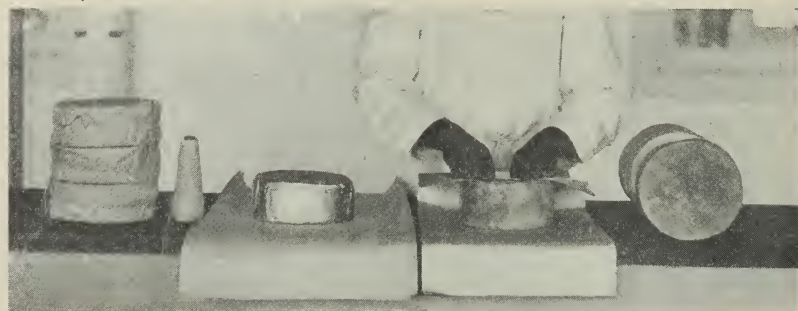


Fig. 8.—Wrapping the cheese in foil and parchment paper.

Losses in curing.—In Roquefort cheese, made from cow's milk, the average loss from scraping, brushing and handling is 7.4 per cent, which seems to be less than the loss in sheep's milk Roquefort.¹ The losses in goat's milk Roquefort in our work were very small on account of the firmness of the cheese.

The loss from shrinkage will vary, according to the moisture content of the cheese at the time it is wrapped in foil, the temperature, and the time held before shipment. Even under the best conditions, there is some shrinkage due largely to evaporation and leakage of whey.

Yield.—Goat's milk with an average butterfat content of 3.4 per cent was used and gave an average yield of 10.34 pounds of cheese for each 100 pounds of milk.

Preparation of mold powder.—Mold powder for inoculation purposes is grown on ordinary white bread. Stock cultures of Roquefort mold should be obtained from a reliable laboratory several weeks before the manufacture of cheese is contemplated.

The mold powder is prepared as follows. Fresh loaves of bread are sterilized by heating in a drying oven for two hours at 170°C. (338°F.). They are then cooled to room temperature. In the meanwhile, a suspension of mold is made by transferring spores from an agar culture of Roquefort mold, by means of a sterile platinum needle, to a flask of sterile water and shaking.



Fig. 9.—Inoculating bread with a pure culture of Roquefort mold.

A sterilized (1 c.c.) pipette is then filled with this suspension and the bread inoculated by allowing a small quantity of the suspension to flow into numerous holes previously punched with a sterile glass rod or a sterile pipette (see fig. 9). At least one ounce of the suspension should be used for each pound of bread and the punctures well distributed to insure an abundant growth of mold in all parts of the loaf. The inoculated bread is put into a moist cold place (48°F.) and left for several weeks to allow the mold to develop to the stage suitable for use in the cheese. This stage is indicated by the spreading of the green mold throughout the bread.

The Roquefort mold develops more vigorously in the cheese and is less likely to be contaminated with foreign molds when grown at a low temperature. When there is evidence of foreign mold in the bread, either the infected part should be removed or the entire loaf

discarded. Since Roquefort mold grows rapidly at a low temperature in the presence of carbon dioxide gas, foreign molds cause but little trouble in the cheese. This is especially true with Roquefort mold grown in bread at a temperature of 48°F.

When the bread is completely invaded by the mold it is thoroughly dried and then sliced and ground in a coffee grinder or with a rolling pin fine enough to pass through a salt shaker. It should be kept in a cool dry place to prevent the absorption of moisture. Before drying, the mold in bread is light green, but upon drying it darkens. It will keep for several months in a dark, dry place.



Fig. 10.—Roquefort cheese packed in excelsior, sawdust or shavings.

Methods of packing.—Roquefort cheese is marketed in wooden boxes, either pine, white-fir, or spruce, holding three, six or twelve cheeses each. The twelve-cheese boxes are 8 in. by 8 in. by 3 feet 9 in., inside dimensions. They are divided into three or four compartments to hold three or four cheeses each. The sides, top, and bottom, are $\frac{3}{8}$ in. thick, and the ends and compartment pieces $\frac{11}{16}$ in. thick. The six and three-cheese boxes are made proportionally smaller from similar material (fig. 10).

The cheese is covered with foil which should be wrapped neatly and securely about it. The dimensions of the foil are 22 in. by 13 in., and there are from eighteen to twenty-five sheets to a pound. The foil is separated from the cheese by a layer of thin paper to which it is attached. Ordinarily, the trade name and design are printed in

black upon the foil. When the cheeses are ready to ship, they are wrapped in strong paper and tied with a cord. This holds them in shape and gives protection in transit. The net weight of cheese is marked on the paper.

The wrapped cheese is then packed in sawdust, pine shavings, or excelsior, which is needed to absorb any leakage brought about by a change from low to high temperatures. No difficulty has been encountered from the cheese absorbing odors from the box or packing materials.

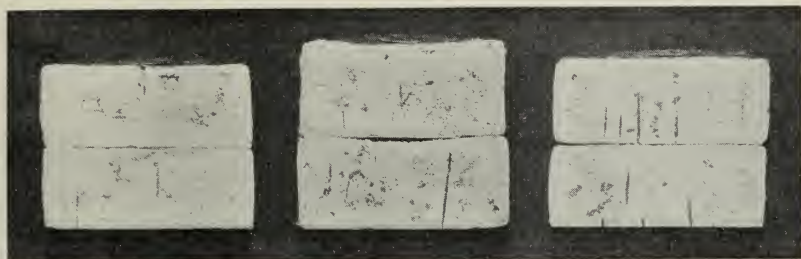


Fig. 11.—Mold growth in goat's milk Roquefort cheese made at the University Farm.

POSSIBILITIES FOR GOAT'S-MILK ROQUEFORT CHEESE

The making of goat's-milk Roquefort cheese is strictly a factory process, and should not be attempted either on the farm or in a commercial plant by inexperienced operators or where equipment for proper curing conditions is lacking. We recall previous efforts to make Roquefort cheese that have failed, largely because these factors have not received proper consideration.

We believe, however, that there is a great future for goat's-milk Roquefort cheese, since it resembles the imported article so closely. Coöperative manufacturing, if properly organized, might make California just as famous for its goat's-milk Roquefort cheese as Aveyron of southern France is for its sheep's-milk Roquefort.

Because of the excellent quality of the goat's-milk cheese, and its resemblance to the imported, the selling price of the two has been practically the same. A record of the sales, both retail and wholesale, was kept and sufficient repeat orders were received to make it safe to conclude that the cheese was satisfactory.

EQUIPMENT FOR ROQUEFORT CHEESE MANUFACTURE

The following equipment is necessary, in addition to the curing rooms described above, for a factory handling 1500 pounds of milk daily:

TABLE 5
EQUIPMENT FOR ROQUEFORT CHEESE MANUFACTURE

Equipment	Number	Capacity or size
Boiler.....	1	5 horse power
Case knives.....	6	
Cheese vat.....	1	200 gallons
Compressor.....	1	5 tons
Conductor head.....	1	
Conductor trough.....		4 inches
Curd pails.....	2	2 gallons
Curd scoops.....	2	1 gallon
Draining mats.....	25	10 inches by 24 inches
Drain vat.....	1	200 gallons
Hand truck.....	1	30 inches by 60 inches
Hygrometer.....	1	Wet and dry bulb, 30° to 140° F.
Punches.....	2	8 inches
Roquefort hoops.....	75	5 pounds
Scales.....	1	1000 pounds
Starter can.....	1	20 gallons
Thermometers.....	6	20° to 220° F.
Vertical curd knife.....	1	8 inches
Wash sink.....	1	2 feet by 3 feet
Weigh can.....	1	50 gallons
Whey separator.....	1	1350 pounds

In addition to the equipment listed (table 5) the following supplies are needed: cheese boxes, drain cloth, mold powder, rennet, salt, strainer cloth, lactic starter, tin foil or aluminum foil, twine, and wrapping paper.

COST OF MANUFACTURE

The figures given on cost of manufacture are based upon milk testing 3.67 per cent fat and costing \$2.16 for 100 pounds. The average yield of cheese was 11.6 pounds for each 100 pounds of 3.67 per cent milk. Part of this cheese was made from goat's milk, part from cow's milk, and part from mixtures of the two.

The labor was figured as one man to each 1000 pounds of milk, and the cost of labor at \$125 a month of twenty-six working days. The average weight of a cheese was 4.87 pounds.

TABLE 6
ESTIMATED COST OF PRODUCING ROQUEFORT TYPE CHEESE

Item	Cost per pound cheese
Cost of milk.....	\$0.2220
Cost of refrigeration.....	0.0655
Cost of water and steam.....	0.0010
Cost of salt.....	0.0002
Cost of rennet.....	0.0001
Cost of labor.....	0.0415
Cost of foil.....	0.0082
Cost of wrapping paper and string.....	0.0018
Cost of boxes.....	0.0069
Interest, taxes, insurance.....	0.0290
Depreciation on building and equipment.....	0.0215
Cost of electricity.....	0.0100
Total cost per pound.....	\$0.4077

The estimated cost of producing Roquefort type cheese (table 6) will vary according to the price paid for the milk and the quantity of cheese manufactured. It is not the desire of the authors to recommend a price for goat's milk. The price quoted above was the price "for manufacturing purposes" paid by the University Farm Creamery for milk containing 3.67 per cent of butterfat. Goat's-milk Roquefort cheese cannot be produced profitably on the basis of the "market-milk" price for goat's milk.

SUMMARY AND CONCLUSIONS

Roquefort type cheese can be manufactured successfully from goat's milk, cow's milk, or mixtures of the two. Judges and purchasers found the goat's-milk Roquefort to be equal in quality to the imported cheese.

The Roquefort cheese process is strictly a factory process. The temperature, humidity, and ventilation of the draining, salting, and curing rooms must be controlled accurately. The following procedure is recommended for handling goat's milk. (Fresh, clean milk is necessary for a good quality of cheese. The acidity test should be between .16 and .18 per cent.)

Three or four per cent of clean lactic starter is used and three to four ounces of rennet is added at a temperature of 82°F. after an acidity of .21-.22 per cent has been developed. The length of time of coagulation should be from one to one and one-half hours. When a thin film of whey spreads over the surface, the curd is cut two ways with a coarse, vertical knife with wires from five-eighths inch to one inch apart.

Ten minutes after cutting, the curd is transferred with scoops into the draining vat. About thirty minutes after dipping, the curd and mold are placed in the hoops, in four or five alternating layers.

The cheese is turned several times during the first day, and twice daily thereafter, while in the drain room. The hoops may be left on the cheese for one or two days. The cheese remains in the drain room four or five days.

The cheeses are salted two or three times at two-day intervals. After from ten to fourteen days in the salting room, they are punched in from twenty to fifty places. They are then placed in the curing room on edge instead of flat. They remain in the curing room for two or three months, and are scraped three or four times. After this period they are wrapped in foil and parchment paper and held for at least two months longer.

The average yield of Roquefort cheese from goat's milk testing 3.4 per cent butterfat was 10.34 pounds for each 100 pounds of milk.

The butterfat losses in the whey from goat's milk are excessive. These losses may be decreased by adding about 20 per cent of cow's milk.

Roquefort cheese made from goat's milk is very white in color, similar to the imported Roquefort made from sheep's milk.

It is probably not advisable to manufacture goat's-milk Roquefort cheese if the cost of production exceeds forty cents a pound, because of the present low wholesale prices of imported Roquefort.

ACKNOWLEDGMENTS

It was through the close coöperation of the Bureau of Dairying, United States Department of Agriculture, that the development of this process in California was possible.

The authors desire to express their appreciation to Professors G. H. True and W. M. Regan of the Animal Husbandry Division, under whose direction the milk was produced; to Mr. A. W. Farrall, who supplied data on refrigeration and electricity, and to the other members of the Dairy Industry Division who gave helpful suggestions.

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